

EXECUTIVE SUMMARY
TO
EFFECTS OF SO₂ ON GROWTH AND YIELD OF WINTER CROPS GROWN
IN SOUTHERN CALIFORNIA

Final Report
to the
California Air Resources Board
Contract No. A3-057-33
November 14, 1983 - February 13, 1985

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September 1985

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EXECUTIVE SUMMARY

California is a major U. S. producer of winter cereal and vegetable crops. Wheat is grown on over 1.1 million acres in the state with a value of approximately \$309 million (2). The crop is planted in the fall and harvested the following summer. Lettuce is grown on approximately 148,000 acres in California and also has a value of \$469 million. Lettuce is planted from November through January with harvests from April through May. Major wheat and lettuce production areas in California have relatively low winter oxidant levels, but there is a possibility for occasional sulfur dioxide exposures from current or potential point sources such as fossil fuel electrical generating plants.

In general, studies have not been conducted on the effects of air pollutants on crops grown during the winter in regions of the United States such as California which have mild winter environmental conditions. The vast majority of field air pollutant studies have been conducted with crops exposed under late spring to fall growing conditions, especially during the warmest months. This lack of winter crops research may be in part due to the generally lower air pollutant levels (especially oxidants) in winter than summer. However, plants are more sensitive to air pollutants under the lower light and higher humidity conditions of winter than summer (4), indicating that the importance of winter exposures should not be ignored for crops.

The sensitivity of crops to sulfur dioxide had been reported to be much greater in winter than summer. Bell et al. (1) reported that perennial ryegrass exhibited reduced yield with continuous exposure to a minimum of $52 \mu\text{g m}^{-3}$ sulfur dioxide for six months during the winter compared to $105 \mu\text{g m}^{-3}$ required for the effect during the summer. Davies (3) indicated that this greater sensitivity during the winter may be associated with lower light intensities.

Information concerning the sensitivity of wheat and lettuce to air pollutants in the field is very sketchy. No results have been reported on the effects of sulfur dioxide on wheat during any time of the year anywhere in the United States. Lettuce yield was increased by 30% with exposure to $786 \mu\text{g m}^{-3}$ sulfur dioxide for 75 days during the winter (8). Wheat yield was decreased by 10-16% when exposed to 196 versus $59 \mu\text{g m}^{-3}$

ozone for seven weeks in late spring (5,6). Lettuce yield was decreased by 50% when exposed to 196 versus 78 $\mu\text{g m}^{-3}$ ozone in late summer (5,6).

The objective of this study was to ascertain the sensitivity of wheat and lettuce to sulfur dioxide or ambient oxidants when plants are exposed under California conditions, and to obtain dose response information from those exposures. The exposures were conducted in the winter, the time when lettuce and wheat are grown in California. The sulfur dioxide concentrations ranged from a low background concentration possible around sulfur dioxide point sources in California, to a high concentration possible only under unusual fumigation conditions. Important California cultivars of the crops and commercial growing practices were used. The response of the crops to the air pollutants was evaluated in terms of commercially important yield, and in terms of growth and physiology.

The study was conducted in the ARB open-top field chambers at the University of California at Riverside. The chambers were cylindrical, 3 m in diameter by 2.43 m in height according to the National Crop Loss Assessment design (5) as modified by Kats et al. (7). Sulfur dioxide gas was dispensed into the chambers from a pressurized tank of liquid sulfur dioxide. Oxidant treatments were achieved by either filtering or not filtering the air entering the chambers. All sulfur dioxide treatments received filtered air. There were five chamber treatments: nonfiltered air and no sulfur dioxide, filtered air and no sulfur dioxide, and filtered air plus approximately 79, 183 or 393 $\mu\text{g m}^{-3}$ sulfur dioxide. One treatment consisted of outside control plots. All treatments were replicated in four chambers or outside plots.

Wheat was planted directly into the chamber or outside soil on 12/15-16/83. Lettuce was started in an artificial media in charcoal-filtered greenhouses on 11/29/83 and transplanted into the soil on 12/19-21/83. The pollutant treatments began on 1/18/84. Plants were watered, fertilized, and received pesticide sprays as needed.

A first harvest of lettuce was made on 2/1-2/84 after approximately 14 days of exposure. Parameters measured were planar leaf area, stomatal conductance, net photosynthesis, fresh weight, dry weight and leaf area. A first harvest of wheat was made on 2/9-10/84 after 22 days of exposure. Parameters measured were height, dry weight, fresh weight, leaf area, number of tillers, chlorophyll content, leaf injury, buffering

capacity and total sulfur content. The final harvest of lettuce was on 3/13-19/84 after 47 days of exposure. Parameters measured were total fresh weight, head weight, total dry weight, plant diameter and head circumference. The final harvest of wheat was on 5/15-16/84 after 118 days of exposure. Parameters measured were stomatal conductance, net photosynthesis, leaf injury, total dry weight, ear weight, total seed weight, 100 seed weight and number of ears.

Sulfur Dioxide Effects. Sulfur dioxide produced significant decreases in wheat physiology, growth and yield. Significant effects occurred with as low as $79 \mu\text{g m}^{-3}$. At the first harvest, sulfur dioxide at $183 \mu\text{g m}^{-3}$ produced small reductions of 5 and 14% in plant height and leaf area, respectively. Sulfur dioxide produced visible chlorotic injury on wheat leaves at 183 and $393 \mu\text{g m}^{-3}$ which was associated with a significant increase in leaf total sulfur content. Even the lowest concentration of $79 \mu\text{g m}^{-3}$ sulfur dioxide decreased the buffering capacity of leaves, indicating an altered plant metabolism. At the final harvest, the commercially important total seed weight was reduced by 31% at $393 \mu\text{g m}^{-3}$. One hundred seed weight was reduced by 8, 12 and 29% by 79, 183 and $393 \mu\text{g m}^{-3}$ sulfur dioxide, respectively.

While the most important yield effects happened only at the highest sulfur dioxide concentration, the occurrence of effects with as low as $79 \mu\text{g m}^{-3}$ sulfur dioxide indicated that wheat may be detrimentally affected at levels of sulfur dioxide that could occur in the field during the winter. The injury symptoms with as little as $183 \mu\text{g m}^{-3}$ after only 22 days of exposure during the coolest part of the growing season indicated that wheat may be especially sensitive to sulfur dioxide in winter, as described previously for other cereals (2).

However, the sulfur dioxide effects during the winter are species specific. Lettuce showed no indication of any detrimental effects from sulfur dioxide on yield, growth or physiology at either harvest. The 26% decrease in wheat yield with $393 \mu\text{g m}^{-3}$ sulfur dioxide was within the range in yield reductions reported for other cereals exposed to similar sulfur dioxide concentrations in the winter. However, since no comparable

summer exposures with wheat were conducted, it was not possible to determine if the plants were made more sensitive to sulfur dioxide by the cooler winter growing conditions.

Oxidant Response. The ambient oxidants occurring between January and early May had little effect on either wheat or lettuce. Wheat had a 6% significant reduction in height at the first harvest and a 9% reduction in 100 seed weight at the final harvest in filtered compared to nonfiltered chambers. Both of these reductions were small and may have been artifacts instead of true effects. The economically important wheat total seed weight was not affected at the final harvest. Lettuce did not show any response to ambient oxidants at either harvest. The low oxidant levels throughout the study (an average of 80 to 90 $\mu\text{g m}^{-3}$ ozone) were likely associated with the lack of any observable ambient air effects.

Chamber Effects. The most dramatic growth effects observed in the study were not the result of any air pollutant treatment, but occurred between chamber-grown and outside plants. For wheat there were significant increases in growth at the first harvest, i.e., 24% in height and 56% in leaf area for chamber versus outside plants. The number of tillers per plant was decreased by 40% in chamber versus outside plants. By the final harvest total seed weight, 100 seed weight and ear weight were increased by 53, 22 and 45%, respectively, for chamber versus outside plants. The senescence of flag leaves for chamber plants was much less than for outside plants. For lettuce at the first harvest there were very large increases of 196, 117 and 235% in fresh weight, dry weight and leaf area for chamber versus outside plants. At the final harvest lettuce head fresh weight was 62% greater for chamber than for outside plants. However, total fresh weight was similar and total dry weight was actually lower for chamber than for outside plants. The lettuce plants apparently grew faster in outside plots than in chambers during the final part of the study.

The dramatic chamber effects showed that open top field chambers are not the most proper system for exposing winter grown crops to air pollutants. The chambers themselves significantly increase plant growth, probably due to the higher chamber soil and air temperatures compared to outside plots.

In conclusion, this study clearly indicated the potential for adverse effects to winter crops in California from relatively low levels of sulfur dioxide. In contrast, ambient levels of oxidants do not appear to cause injury to plants in the winter. Additional research on winter crops in California is suggested according to the following recommendations:

(1) Conduct the sulfur dioxide exposures using a chamber-less zonal air pollution (ZAP) system and not open top field chambers. Open top field chambers are not recommended as the dramatic increases in plant growth in chambers indicated that air pollution sensitivity may be quite different in chambers versus outside fields.

(2) Use a variety of winter grown California crops representing different commercially valuable plant parts, i.e., roots versus leaves, and different plant families.

(3) Begin the winter crops exposures earlier in the fall, i.e., mid-November, in order to include more of the coolest part of the growing season.

(4) Develop the use of buffering capacity or other physiological parameters as early indicators of sulfur dioxide effects on winter crops.

References

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